Master on Industrial Electronics and Computers Engineering

Specialization on Control, Automation and Robotics

Autonomous Intelligent Systems 2023/2024:

Robotic Welding Lecture

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Agenda:

- Introduction
- Overview of Welding
- Evolution of Welding Technology
- What is Robotic Welding?
- Applications of Robotic Welding
- Robotic Welding Characteristics
- Robotic Welding Techniques
- Challenges in Robotic Welding
- Case Studies
- Advantages of Robotic Welding
- Disadvantages of Robotic Welding
- Future Trends in Robotic Welding
- Conclusion

Introduction

Goals of this lecture:

- Learn about the different types of welding technologies
- Understand the fundamentals of robotic welding technology
- Explore its multiple applications across different industrial sectors
- Discuss the advantages, challenges, and future trends in robotic welding

Overview of Welding

Definition of Welding:
“A fabrication process whereby two or more parts are fused together by means of heat, pressure or both forming a join as the parts cool” [1]

Importance of Welding:

- Facilitates the creation of structures, products, and components across different industries
- Enables the assembly of complex structures, ensuring structural integrity and longevity
- Critical role in different sectors, such as automotive, aerospace, construction, shipbuilding, and more.

Overview of Welding

Welding Techniques

Traditional Methods

- Arc Welding
- Gas Welding
- Resistance Welding

Modern Techniques

- Laser Welding
- Electron Beam Welding
- Friction Welding

Overview of Welding

Traditional Methods

Arc Welding:
Utilizes an electric arc to melt and join metals

Arc Welding: https://www.differencebox.com

Arc Welding Types [2], [3]:

1. **SMAW (Shield Metal Arc Welding)**
- Consumable electrode
- Electrode is mostly made of ferrous materials.

2. **GMAW (Gas Metal Arc Welding)**
- Consumable electrode
- Electrode can be varied according to desired result
- Also known as Metal Inert Gas (MIG)

3. **GTAW (Gas Tungsten Arc Welding)**
- Non-consumable electrode
- Suitable only for autogenous mode
- Also know as Tungsten Inert Gas (TIG)

Overview of Welding

Traditional Methods

Arc Welding:
Utilizes an electric arc to melt and join metals

SMAW (Shield Metal Arc Welding)

Overview of Welding

Traditional Methods

Gas Welding:

"Oxy-acetylene gas welding is one of the oldest methods of welding and, for many years, was the most widely used welding technique." [4]

Gas Welding: https://www.xometry.com/resources/sheet/types-of-gas-welding/

Gas Welding Types [6]:

1. **MIG (Metal Inert Gas Welding)**
   - Create an arc welding using gas
   - The gas is only used to generate the arc

2. **MAG (Metal Active Gas Welding)**
   - Create an arc welding using gas
   - Gas is typically CO_2
   - The active gas increases the electrical voltage, which increases the heat

3. **Oxy-Acetylene Welding**
   - Most common type of gas welding
   - Uses oxygen and acetylene to created a high-temperature flame

Gas Welding Characteristics [5]:

1. Easy to use
2. Portability (No electricity supply needed)
3. Lower Temperatures compared to Arc Welding
4. Good control of melting
5. Requires Post-Welding Finish

Overview of Welding

Traditional Methods

Gas Welding:

“Oxy-acetylene gas welding is one of the oldest methods of welding and, for many years, was the most widely used welding technique.” [4]

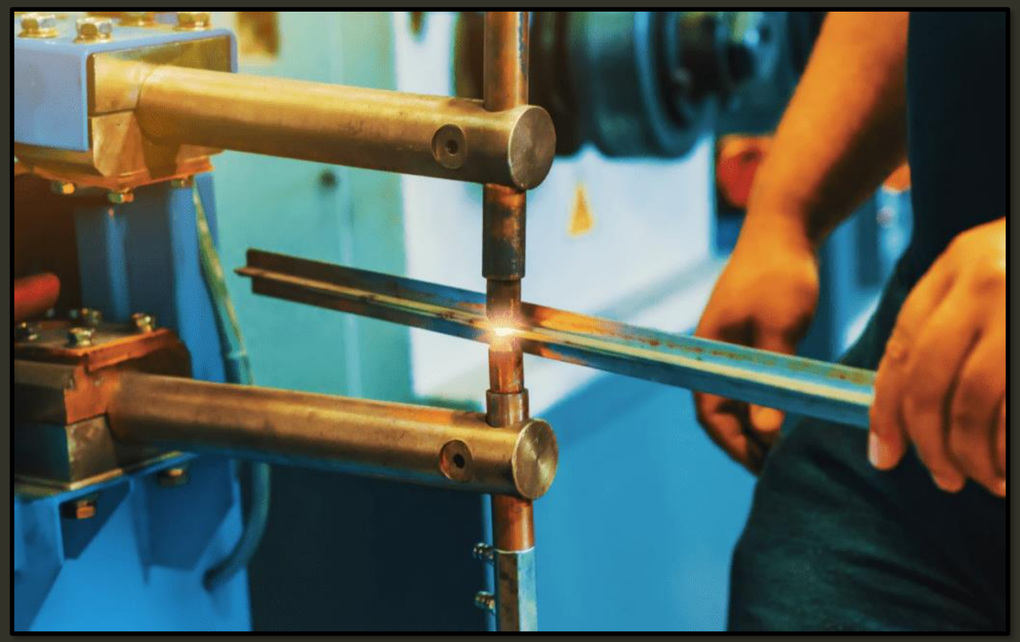
Oxy-Acetylene Welding

Overview of Welding

Traditional Methods

Resistance Welding:

“Resistance welding involves passing an electric current through the components being joined to heat the interface enough to cause melting of the materials at the interface.”[7]



Spot Welding: https://tjsnow.com/resources/what-is-resistance-welding/

Resistance Welding Types [8], [9]:

1. **Resistance Spot Welding**
- Oldest and simplest forms of resistance welding
- Extensively used in automotive and aerospace industries
- Weld nugget is produced by passing an electric current between two metals

2. **Resistance Seam Welding**
- Variation of spot welding
- Instead of a spot one nugget, a series of overlapping nuggets is produced

3. **Resistance Projection Welding**
- The electricity, force, and weld time are concentrated on raised ‘projection’ across a surface
- Typically used for thicker materials rather than the thinner metal pieces that spot welding is usually required for

Overview of Welding

Traditional Methods

Resistance Welding:
“Resistance welding involves passing an electric current through the components being joined to heat the interface enough to cause melting of the materials at the interface.”[7]

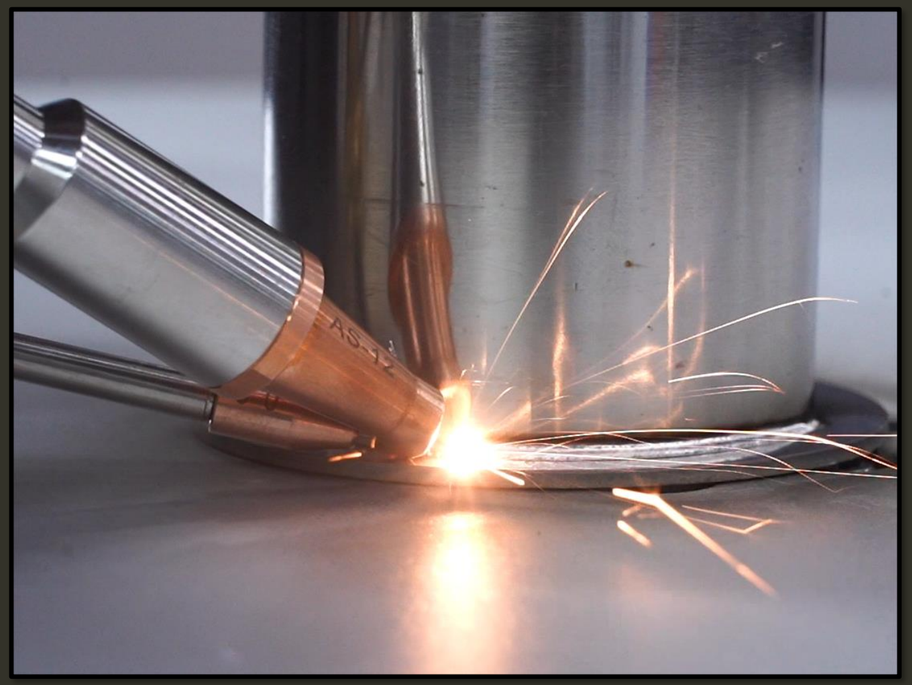
Resistance Spot Welding

Overview of Welding

Modern Techniques

Laser Welding:

Laser welding is a precise process of fusing metal parts using a beam of laser light.



Laser Welding: https://www.heatsign.com

Laser Welding Types [10], [11]:

1. **Conduction Welding**
- Lowest power rating of any laser-based approach
- Merges the melted edges by capillary action alone, with no filler
- Best suited to welding precisely fitted edges of thin materials

2. **Deep Penetration Welding**
- Suitable for welding thicker materials
- The laser firstly cuts a keyhole that penetrates through the material, then the hole is closed with a molten filler rod

3. **Laser Spot Welding**
- Best used for small, complex parts
- Creates small, localized edges that can make point joints between edges, or melt through one part to merge with the part below

Laser types used:

1. CO_2 Lasers
2. Nd: YAG (Neodymium-doped Yttrium Aluminum Garnet) Lasers
3. Fiber Lasers
4. Disk Lasers

Overview of Welding

Modern Techniques

Laser Welding:
Laser welding is a precise process of fusing metal parts using a beam of laser light.

Laser Spot Welding

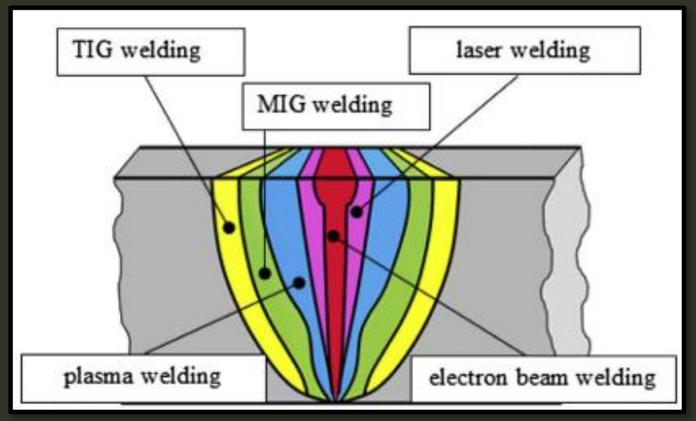
Overview of Welding

Modern Techniques

Electron Beam Welding:

“Electron beam (EB) welding is a fusion welding process whereby electrons are generated by an electron gun and accelerated to high speeds using electrical fields.”

EBW: https://www.twi-global.com



Electron Beam Welding Types [12], [13]:

1. **Thermal EBW**
- Most common type of EBW
- Precise and with a high accuracy
- An Electron beam is focused onto a piece of metal using a vacuum chamber. The electrons interact with the metal atoms and create heat, which melts the metal and welds it together with another piece

2. **Cold EBW**
- Similar to Thermal EBW, but does not use heat to melt the metal
- Instead, uses an intense electron beam to physically break molecules and bonds within the material being welded together
- Allows extremely small and intricate welds that would be impossible with other welding techniques

Overview of Welding

Modern Techniques

Electron Beam Welding:

“Electron beam (EB) welding is a fusion welding process whereby electrons are generated by an electron gun and accelerated to high speeds using electrical fields.”

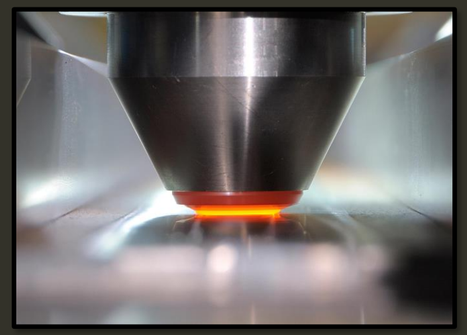
Thermal Electron Beam Welding

Overview of Welding

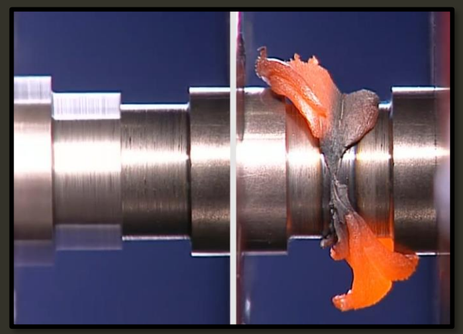
Modern Techniques

Friction Welding:

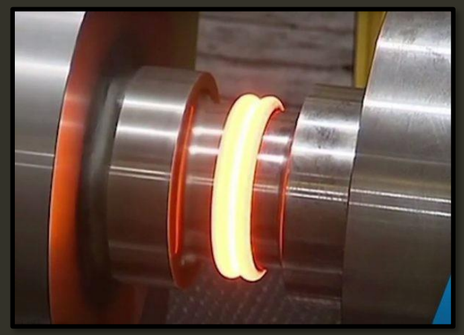
"Friction welding is a solid-state joining process which can produce high quality welds between two components with either similar or different compositions." [14]



FSW: https://www.twi-global.com



LFW: https://www.businessinsider.com/



RFW: https://www.linkedin.com

Friction Welding Types [15]:

1. **Friction Stir Welding (FSW)**
- Most common type of friction welding
- Non-Consumable tool that applies pressure and heat to two pieces of metal, which are then stirred together to form a bond

2. **Rotary Friction Welding (RFW)**
- Uses heat and torque generated by rotating tools to join parts under pressure
- RFW can produce high-strength welds in a wide range of materials
- Also known to produce very smooth finishes on components

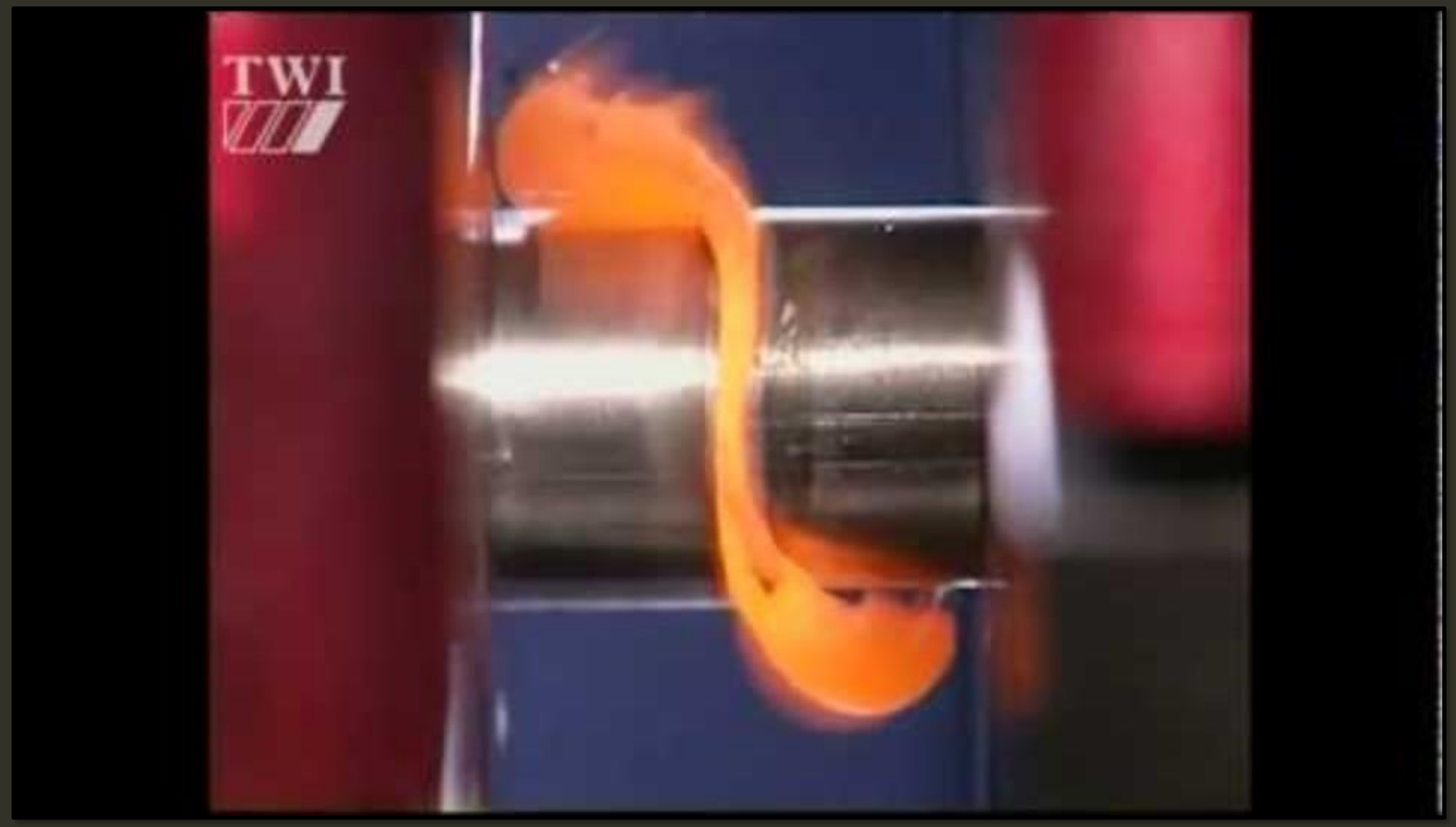
3. **Linear Friction Welding (LFW)**
- Uses linear motion rather than rotation while applying heat and pressure between two materials to produce strong bonds
- Can be used on a variety of materials
- Produces strong bonds with minimal distortion due to its uniform heating pattern along the entire length of the joint seam

Overview of Welding

Modern Techniques

Friction Welding:

“Friction welding is a solid-state joining process which can produce high quality welds between two components with either similar or different compositions.” [14]



Linear Friction Welding

Evolution of Welding Technology:

1800-1802
- First stable electric arc, enabling metalworkers to melt metals

1836
- Discovery of Acetylene

~1850
- Creation of electric generator
- Gas welding first used

1881
- Carbon Arc Welding – first practical arc welding process

1888
- Utilization of metal electrodes for arc welding

1900
- First commercial oxyacetylene welding torch
- Resistance welding

Evolution of Welding Technology:

1920
- Widespread adoption of arc welding;
- Automatic Welding;

1930s-40s
- Gas Tungsten Arc Welding (GTAW)
- Gas Metal Arc Welding (GMAW)
- Submerged Arc Welding (SAW) – popular automatic process

1940s-50s
- Development of the first microprocessor-controlled robot
- Electron Beam Welding

1970s-80s
- Development of CAD/CAM systems for robot welding programming
- Introduction of the first articulated six-axis robots

1990s
- Advanced computer vision is integrated into robot welding systems
- Friction Stir Welding is invented

2000s to Present
- Robot welding continues to evolve with the incorporating of artificial intelligence
- Integration with Industry 4.0 Principles

What is robotic welding?

"Robotic Welding is an automated welding technique that is performed by a welding robot"

Reference:

- Universal Robots (2022), "What is Robotic welding? 7 Popular Robot Welding Types & Process"

Applications of Robotic Welding

Applications of Robotic Welding

Automative:

- Precise and quick results;
- Large assembly lines;
- Greater safety and efficiency

Applications of Robotic Welding

Aerospace:

- Uses the Gas Tungsten Arc Welding process;
- Touch-screens interfaces for motion programming;
- Weight reduction.

Applications of Robotic Welding

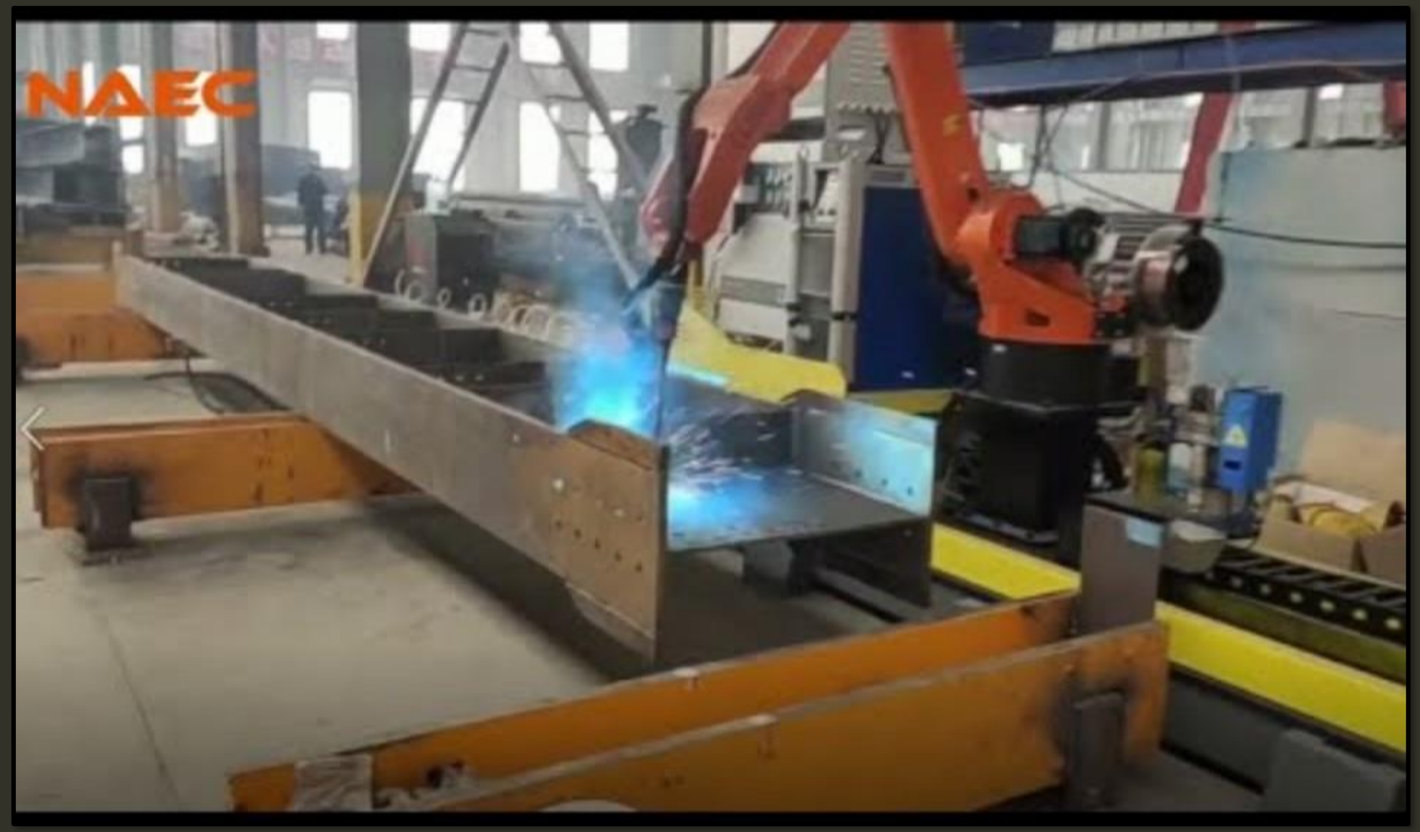
Metal Fabrication:

- Welding of large and heavy parts;
- Efficiency and consistency;
- Integration with manufacturing processes

Applications of Robotic Welding

Construction:

- Less worker error;
- Accuracy, reliability and repeatability;
- Component manufacturing;



Robotic Welding Characteristics

Robotic Welding Characteristics

Robot Types Used for Welding

Technically, any type of stationary robot can be used in a welding application. These robots' types include:

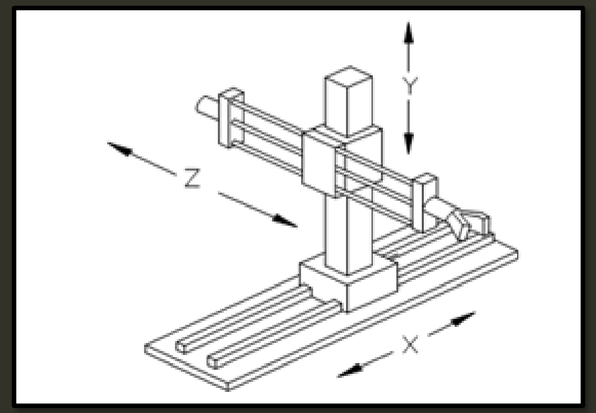
A. Cartesian or Gantry;

B. Articulated Robots;

C. SCARA Robots;

D. Cylindrical.

A.



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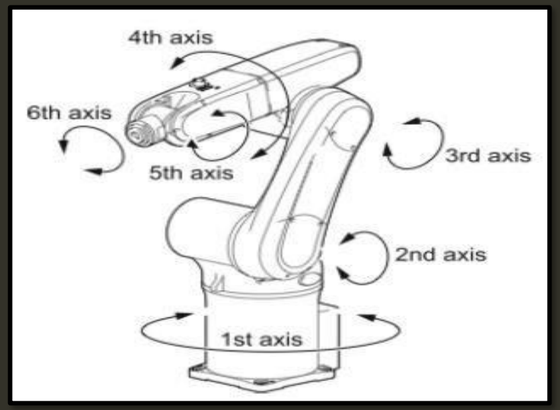

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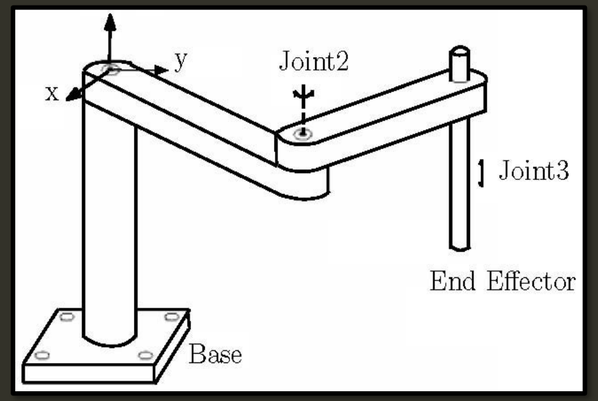

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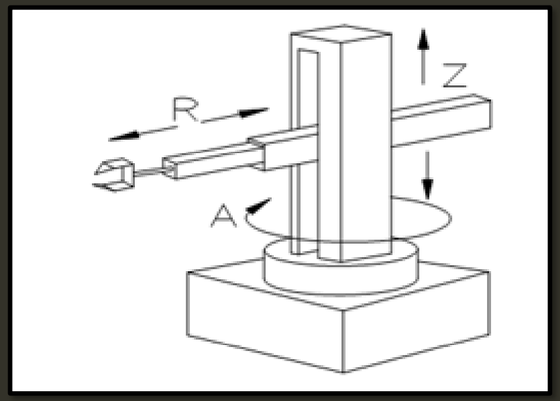


Robotic Welding Characteristics

Robotic Welding Programming

Robotic Welders are typically programmed in one of three ways:

- Hand-teaching or app-based tools;
- Teach Pendant;
- Offline Programming.

Robotic Welding Characteristics

Welding Risks

The welding process is an inherently dangerous one. These dangers include:

- Electrical shock;
- Sound;
- Arc exposure;
- Explosive hazards.

Any process that includes high-voltage electricity and high temperatures will be dangerous for humans. Manual welders are always exposed to these hazard during the welding process. Potential injuries include:

- Burns;
- Electrocution;
- Hearing loss;
- Blindness.

Robotic Welding Characteristics

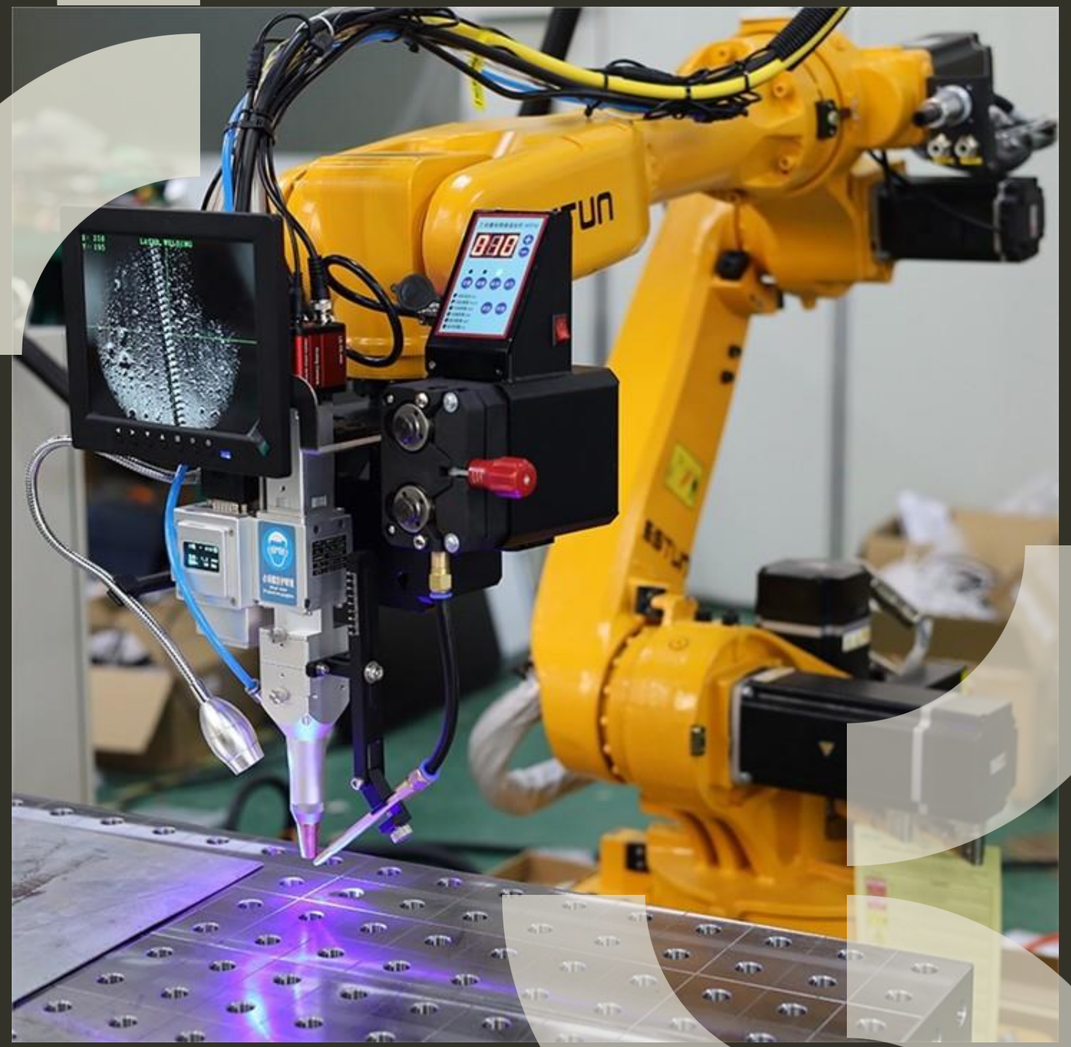
Safety

By incorporating a welding robot, you remove the person from the immediate hazard. The robot is handling the active welding task. This includes operating the torch and sometimes manipulating the workpiece, which are the most common points of injury for welders.

Even Though we remove humans from welding, there are risks associated with the use of industrial robots, so it is necessary to include some standard safety measures such as:

- Safety cage;
- Safety scanners;
- Sensors;
- Safety relays;
- Door Locks;

Robotic Welding Techniques



Robotic Welding Techniques

Some of the welding operations that can be performed by robots are as follow:

- Arc Welding;
- Spot Welding;
- TIG Welding;
- MIG Welding;
- Laser Welding;
- Plasma Welding.

Arc Welding Robot:
https://www.fanuc.eu/pt/

Resistance Welding Robot:
https://www.fanucamerica.com

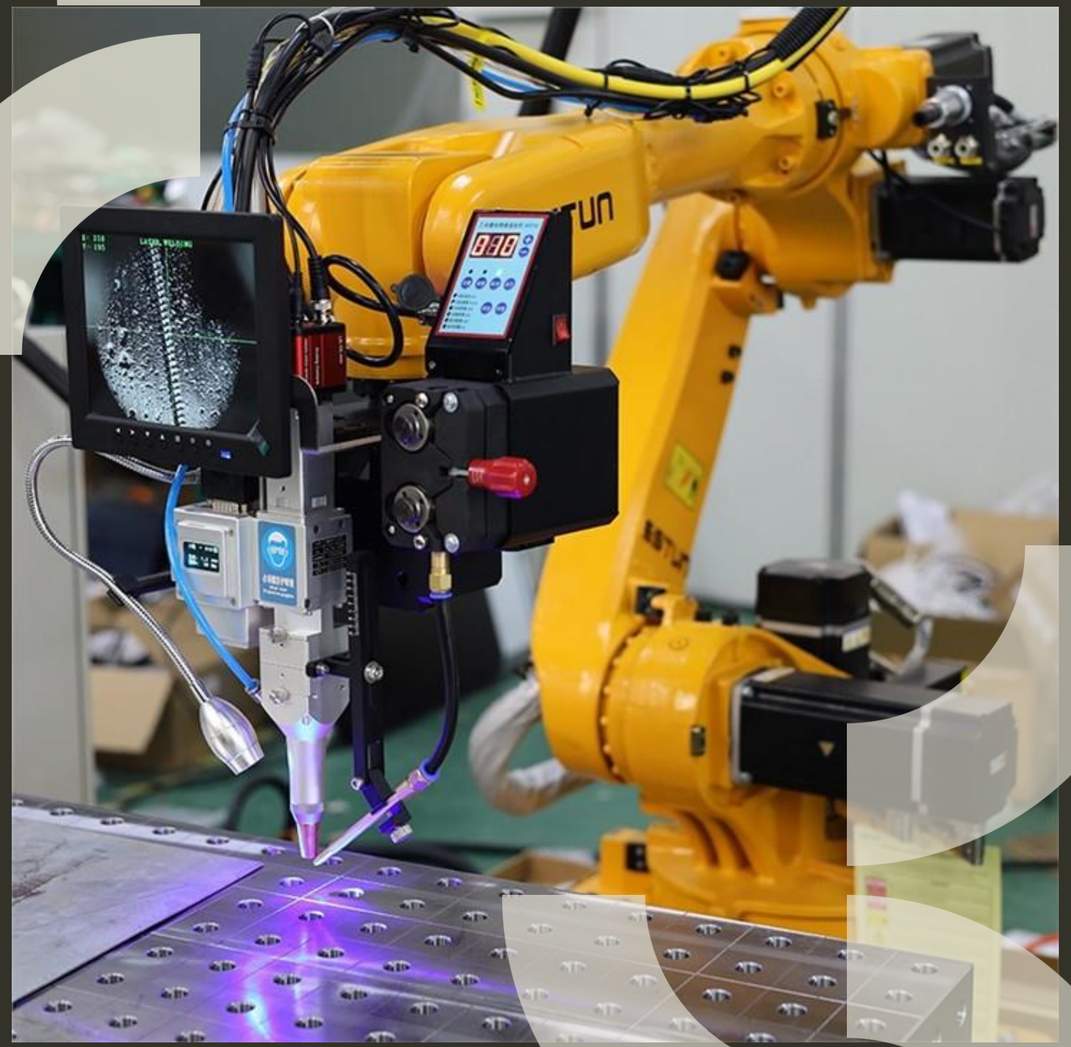
TIG Welding Robot:
https://www.geniusrobotics.cn

MIG Welding Robot:
https://www.tradechina.com/

Laser Welding Robot:
https://www.laseral.com.tr/

Plasma Welding Robot:
https://www.directindustry.com

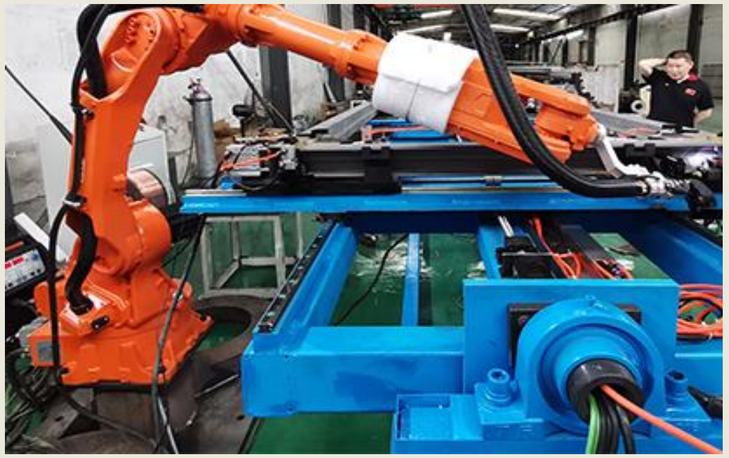
Case Studies



Door Frame Welding

Features:

- Tooling length/width adjusting makes it suitable for different frame sizes;
- It can change to a laser welding source if the frame is very thin.



Forklift Frame Welding

Features:

- Robot control manages dual-axis positioner and cleaning station, streamlining coordination and saving space;
- repetitive positioning accuracy of ± 0.05mm.

Motorcycle Frame Welding

Features:

- QJAR robots in motorcycle production lines ensure quality with CE and ISO certifications, utilizing advanced testing equipment;

Case Studies

Door Frame Welding

Case Studies

Forklift Frame Welding

Case Studies

Motorcycle Frame Welding

Advantages and Disadvantages of Robotic Welding

Advantages of Robotic Welding

Increased productivity:

- Robotic welders get the job done faster, more efficiently;
- They can achieve up to 85% efficiency compared to 20% of their skilled human counterparts;
- Robots can have up to as high as 95% arc-on time.

Constant quality:

- Robots can maintain constant weld speed, current, and other variables, delivering very high weld quality every time;
- Using welding robots for welding projects that need stringent quality requirements is ideal;

Reduce waste and consumables:

- Welding robots eliminate a lot of welding mistakes that come from human welding;
- Welding robots deliver the same weld quality no matter the situation;
- Avoiding scraps makes it easier to stay on budget, especially oh high-value jobs;
- Robotic welders are efficient, so they reduce the amount of waste produced.

Disadvantages of Robotic Welding

Initial Investment:

- While automated welding reduces labor expenses in the long run, the initial costs for the machinery are often substantial.

Maintenance Costs:

- Apart from the initial expense, ongoing machinery maintenance costs need to be considered.

Technical Challenges:

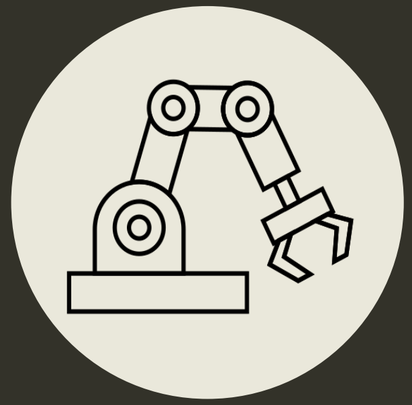
- Automated Welding machinery may encounter technical issues, potentially causing significant downtime for companies reliant on robotic welding.

Limited Versatility:

- Robotic Welding machines excel at repetitive tasks but may require reconfiguration for diverse manufacturing needs, incurring time and potential expenses.

Challenges in Robotic Welding

Combining Welding Knowledge with Programming Skills



Working with Multiple Robot Brands

Keep Up to Date with Technological Developments

Future Trends in Robotic Welding

Future Trends in Robotic Welding

Welding Cobots:

- A skilled welder can work in tandem with robot to automate repetitive and mudane tasks;
- A highly skilled welder can focus on more complicated tasks;
- A cobot is cheaper than a robot but still offers a high level of efficiency;

Future Trends in Robotic Welding

VR- and AR-enabled Training:

- Organizations can use VR and AR technologies to simulate real-world environments, reducing human error and increase productivity;

Future Trends in Robotic Welding

Laser Sensing Technologies:

- With the advancements in this area, companies will be allowed to produce higher-quality welds while giving worker increased to real-time data and analytics which can help them detect and correct welds with ease;

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Thank you!
Any questions?

May the force be with you!